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PROGRESS REPORT OF NHA - USPHS HOUSEHOLD SEWAGE DISPOSAL PROJECT

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of

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The Household Sewage Disposal Project, inaugurated in 1946, required emphasis on special testing and investigation work. Specific areas examined include: literature review; investigation of existing installations; operation of septic tanks and subsurface systems; sampling; laboratory investigation of soil clogging; 10 and 20-year cleaning intervals; extreme freezing conditions; effect of tree and shrubbery roots; effects of residential garbage grinding; distribution boxes; investigation of tank proportions; discharge of grease; relationship of sodium and calcium to soil-clogging action; relationships among seepage, evaporation, and transpiration; new methods of disposal; and development of standards.

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PROGRESS REPORT

of

NHA - USPHS HOUSEHOLD SEWAGE DISPOSAL PROJECT

REPORT

August 1, 1947

U. S. Public Health Service
Sanitary Engineering Division
Water and Sanitation Investigations
Cincinnati, 2, Ohio

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INTRODUCTION

Authorization

The project was inaugurated in November, 1946 through arrangement by conference and exchange of correspondence between representatives of the National Housing Agency, The Office of the Housing Expediter and the Public Health Service, and the assignment of a working fund of $100,000 by the National Housing Agency to the Public Health Service for the conduct of the project.

Objectives

A list of definite projects, developed through joint conferences between staff members of the Technical Service Branch, National Housing Agency and the U. S. Public Health Service, is presented below. It was agreed that specific needs of the housing program at various times may require that increased emphasis be placed on special testing and investigation work in connection with particular items on the list, but in general a work program would be followed and the facilities of the U. S. Public Health Service used in such a manner as to provide the maximum of data on as broad a scope as possible in the shortest possible time. The list of projects is as follows:

1. Collection and analysis of existing data

   A. Review existing publications and unpublished studies both domestic and foreign, regulations, and commercial brochures on the design, capacity, durability of construction materials and operating results of septic tanks and disposal systems and indicate such publications that offer information on acceptable principles to be followed.

   B. Select representative installations of various types for testing and gauging operations.

2. Investigate existing installations of different sizes, shapes, types, and materials, and determine efficiency of sedimentations, durability

of materials, adequacy of sludge storage, and other basic characteristics.

3. Conduct such short term testing and research as may be possible and desirable to substantiate such items as efficiency of sedimentation, adequacy of sludge storage, capacity, size, shape, durability of materials and other comparable characteristics of commercial septic tanks.

4. Locate, construct, or otherwise secure at properly selected field locations and operate, under normal conditions, tanks of some flexibility for trials and pilot studies.

5. Locate, construct, or otherwise secure at properly selected field locations and operate subsurface systems on experimental basis, including experimental seepage test holes, trenches, tile lines, and complete subsurface installations.

6. Initiate sampling, gauging, and testing of several installations representative of current practices.

7. Conduct laboratory investigations on the soil-clogging characteristics of tank effluent.

8. Study the economic and general feasibility of constructing systems with sufficient sludge capacities to require cleaning at only 10 or 20-year intervals.

9. Study the effect of extreme freezing conditions on the functioning of a properly designed and constructed subsurface disposal field and determine what modifications should be incorporated in accepted design practices for cold climates.

10. Study the effect of tree and shrubbery roots on disposal systems and the ability of roots to absorb significant portions of sewage effluent through all seasons of the year.

11. Determine the effect of residential garbage grinding on septic tank operation and what modifications in design should be made to permit this service.

12. Test various distribution box installations as a basis for determining the most efficient design for these structures.

13. Investigate feasibility of changing the ratio of horizontal and vertical areas of septic tanks so as to permit a shorter detention period and increased sludge storage capacity.

14. Study the discharge of normal amounts of grease directly into a septic tank of adequate size and determine the effect of grease on septic action and on the efficiency of septic tank systems.

15. Determine the relation of Sodium and Calcium to the soil-clogging action of the effluent.

16. Investigate the ralationship of (a) seepage, lateral or vertical (b) evaporation and (c) transpiration to the overall efficiency of a subsurface disposal system.

17. Study and investigate new methods of disposal, particularly substitute methods for subsurface disposal.

18. Develop recommended minimum standards of design for septic tank systems.

Personnel

Pending recruitment of personnel for the project the services of several of the engineers of the Cincinnati Station Staff were made available in January to enable an early start. In this connection Sanitary Engineer F. E. DeMartini undertook the preparation of preliminary personnel and budgetary requirements, the preparation of job descriptions, solicitation and review of Civil Service lists, interviewing of applicants and other administrative duties in connection with the staffing of the project, starting in early January. About the middle of January Station Staff Engineer M. LeBosquet, R. S. Smith and R. L. Woodward undertook field trips to contact the U.S.P.H.S. District offices and State Health Department offices in the north central, central and south central sections of the country, to locate areas in which field surveys of existing installations might be conducted to best advantage, as a result of which the Dallas-Ft. Worth, Kansas City and Cook County, Illinois areas were selected for opening field study. Sanitary Engineer M. LeBosquet also undertook to design and supervise construction of automatic gaging and sampling apparatus. In addition to the engineering assignments Principal Chemist C. C. Ruchhoft and the staff of the Chemical Laboratory devoted considerable time to training and orientation of chemists and aides recruited for the project, and to the setting up of a laboratory for the project in the basement

of the Cincinnati Laboratory. Later on Principal Bacteriologist C. T. Butterfield and staff contributed similar assistance concerning the bacteriologist recruited for the study, and provided working space at the Bacteriological Laboratory.

The number and distribution of personnel loaned to the project from the Cincinnati Station Staff, together with personnel hired or transferred from other Service assignments to the N.H.A. project, are as follows, by months:

Number and Distribution of Personnel

	On loan from Station Staff (Salaries paid by P.H.S.)			N.H.A. Project Staff (Salaries from N.H.A. Fund)			
Month	Tech.	Labor	Total	Tech.	Cler.	Labor	Total
Dec.	2	-	2	-	-	-	-
Jan.	6	1	7	1	1	-	2
Feb.	4	1	5	7	1	2	10
Mar.	3	1	4	8	1	3	12
Apr.	2	-	2	8	1	4	13
May	2	-	2	10	1	5	16
June	2	-	2	13	1	9	23
July	2	-	2	13	1	10	24
Person months (whole or part)	23	3	26	60	7	33	100

The N.H.A.-U.S.P.H.S. Project, as of the end of July, 1947, was staffed and assigned as follows, the project being handled as one major activity of the Cincinnati Station under the administrative direction of Sanitary Engineer Director H. W. Streeter, Officer in Charge, Water and Sanitation Investigations:

N.H.A.-U.S.P.H.S. Project Staff

Name	Title and Grade		Assignment
	Engineering - 10		
Weibel, S. R.	P.H. Engr.	P-5	In charge of project.
*Straub, C. P.	S.A.San. Engr.		Conduct research program.
*Thoman, J. R.	S.A.San. Engr.		Central office, review lit., analysis.

Name	Title and Grade		Assignment
Solander, A. A.	P.H. Engr.	P-4	Research, Cincinnati
Retter, H. H.	S.A.Engr.(R)		Field survey, Kansas City, Mo.
Agnano, P.	S.A.San.Engr.(R)		Field survey, Cook Co., Ill.
Shipp, J. W.	S.A.San.(R)		Field survey, Cincinnati
Hamblett, W.	P.H.Engr.	P-2	Research, Cincinnati
Longan, F.E.	P.H. Engr.	P-1	Field survey, Kansas City, Kan.
Edwards, C. H.	Eng. Aide	SP-6	Field survey, St. Joseph Co., Ind.

* On loan from Cincinnati Station Staff.

Scientific - 5

Clark, H. F.	Chemist	P-3	Research, Cincinnati
Cohen, J.	Chemist	P-2	" "
Tubiash, H. S.	Bacteriologist	P-2	" "
George, J. E.	Scientific Aide	SP-4	" "
Dudley, A. V.	Scientific Aide	SP-4	" "

Clerical - 1

Strosnider, M. L.	Clerk Steno.	CAF-3	Central Office, Cincinnati

Labor - 10

Stephenson, C. G.	Skilled Laborer	CPC-4	Cincinnati
Brenneman, A. P.	" "	CPC-4	Kansas City, Mo.
Smith, R.	" "	CPC-4	Cook Co., Ill.
Price, G. W.	" "	CPC-4	Kansas City, Kan.
Greene, F. W.	" "	CPC-4	Cincinnati
Latimer, W. E.	" "	CPC-4	"
Bryan, W. T. Jr.	" "	CPC-4	"
Pepernik, M. C.	" "	CPC-4	"
Peterson, D. D.	" "	CPC-4	"
Smith, N. R.	" "	CPC-4	St. Joseph Co., Ind.

Transportation

Transportation was made available in field areas initially by the U.S.P.H.S. District offices through the loan of one automobile from District Offices 7 and 9 and two automobiles from District Office 3. Arrangements were completed in May for the loan of five cars from F.P.H.A., one being loaned by the Cleveland office and four by the Fort Worth office, enabling the return of the District 7 and 9 cars. The Cincinnati Laboratory shared

the local vehicles to provide initial transportation in the Cincinnati area. The loan of two passenger cars from the Division office and a truck from F.P.H.A. now fills the needs of the project in this area.

Acknowledgement

Grateful acknowledgement is made of the assistance given the project by representatives of the National Housing Agency, Federal Housing Administration and Federal Public Housing Authority, the Public Health Service Engineering Division, and the Cincinnati Station Staff in guidance given at the several conferences and various aids in particulars too numerous to outline; the Public Health Service District Offices for liaison in connection with the opening of field study areas, for providing desk space, transportation and assistance in hiring field labor; the State, County and Municipal Health Departments cooperating in the areas in which study has been or is now being made and those also who offered similar cooperation in their respective areas; the manufacturers of tanks, appurtenances and equipment who made special efforts to expedite delivery of purchases for the project; the universities, engineering schools, agricultural colleges, extension and experiment stations, libraries, individual scientists in the United States and foreign countries, and manufacturers who willingly responded to requests in connection with the review of literature; and finally, the staff of the project, including several medical students taken on as summer laborers and laboratory personnel, which undertook the various assignments, some of which are far from pleasant, with willingness and purpose seldom obtained in a necessarily hastily organized temporary staff.

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REPORT ON PROGRESS

As of July 31, 1947

Report of Progress Individual Projects

1. Collection and analysis of existing data
   A. Review existing publications and unpublished studies both domestic and foreign, regulations, and commercial brochures on the design, capacity, durability of construction materials and operating results of septic tanks and disposal systems and indicate such publications that offer information on acceptable principles to be followed.

Approximately 600 references to articles in periodicals, pamphlets, and books relating to septic tank sewage disposal systems were checked for information. This search of the literature was made primarily to develop information concerning past research projects and general design practice in countries throughout the world. References to research projects were few in number, and the studies described left much to be desired, doubtless due to the expense involved in conducting a thorough research program. Most references treated of design and construction practices, and in practically all cases were based on the author's opinions or experience with a group of installations. In many cases, design data were borrowed from another publication and together with minor changes and embellishments published as representing correct practice.

In the sections following, a review is made of the various factors employed in the design of septic tank systems. A rather detailed summary of the source material is given in Appendix A, as well as the methods used to obtain the information. The complete bibliography developed is included in this appendix and is subdivided by years. An author index for this bibliography is also included.

The household septic tank appears to date back to John Louis Mouras who constructed a masonry tank in which sewage, kitchen wastes and rain water from a small dwelling located in Vesoul, France, were collected before passing into a cesspool. Twelve years later the tank was operated and found, contrary to expectations, almost free of solids. Consequently a series of experiments were then made in collaboration with a priest, Abbé Moigno, a scientific authority of his time. The satisfactory completion of these experiments induced Mouras to patent his invention in 1881. A drawing of the Mouras tank is shown in Appendix B.

In this country the household septic tank appears to date back to about 1883.

Sewage as received by a septic tank sewage disposal system will, in general, be somewhat different in character than that received in a sewage treatment plant. Due to the proximity of the tank to the dwelling unit the sewage will be very fresh, and will consist of the wastes from the various plumbing fixtures in the house. The sewage will include water closet and urinal wastes, lavatory and bath tub discharges, laundry wastes and kitchen wastes. In those houses equipped with a garbage grinder and/or a zeolite water softener, the tank will receive ground garbage and/or regeneration wastes from the softener.

The character of the sewage will differ for each household depending upon the ages and sexes of the members of the family, their economic status, individual habits, diet, and the numbers and types of plumbing fixtures connected to the system. Imhoff and Fair have presented the following table as representing the average composition of domestic sewage in North America.

Average Composition of Domestic Sewage
in parts per million for a flow of 80 gallons per capita daily

	Mineral	Organic	Total	5-day B.O.D. 20°C
1. Suspended solids	85	215	295	140
a. settleable	50	130	180	65
b. non-settleable	35	85	115	75
2. Dissolved solids	265	265	530	40
3. Total	350	480	825	180

While this table represents average conditions, individual dwelling units will vary widely depending upon the factors cited above. The constituents in sewage in solution and suspension as enumerated by Keefer are:

1. Nitrogenous compounds
2. Carbohydrates
3. Fats and soap
4. Mineral matter
5. Gases
6. Living organisms

From the standpoint of treatment of sewage in a spetic tank the first three constituents cited above will be the most important. Other materials that may present special problems when disposed of by a septic tank system are ground garbage and regeneration wastes from zeolite water softeners. A further discussion of these two factors is presented in a later section of this report. Another item that must be considered is the use of drain cleaners in large quantities which may have adverse effects on the biological life in the septic tank.

The quantity of sewage which a septic tank will receive during the period of a day will vary considerable depending on those same factors which affect the character of the sewage. The flow to the tank will be intermittent with sharp peaks and long periods during which no flow occurs. In general, for an individual house the quantity of water used will closely approximate the quantity of sewage received by the tank. However, consideration must

be given in estimating sewage flows by water consumption data, to any factors which might lessen the quantity, such as watering the lawn, cleaning buildings, watering stock on a farm and diversion of wastes from particular fixtures to disposal other than through the septic tank.

Data on per capita water use for individual houses was presented by Pond in 1939 Journal of the American Water Works Association. This data is reproduced below.

Daily per capita water consumption in 1 family houses

	Year	Houses	
Newton, Mass.	1892	490	26.5
Hartford, Conn.	1920	302	43.8
New Haven, Conn.	1937	1519	59.4
West Haven, Conn.	1937	3380	36.8

Pond also gives the following figures for estimating the daily water use.

Basic quantity/individual - 20 gallons/day
(Includes: drinking - 1 gal.
laundry - 6 gal.
ablution - 5 gal.
2 toilet flushes - 8 gal.

Tub bath - 25 gallons

Shower bath - 5 gallons

Additional toilet flush/person - 6 gallons/day

The quantity of 20 gallons per person per day is considered the minimum necessary to allow normal daily functions. In using these figures for preparing an estimate of water consumption in individual cases, consideration should be given to any factors which might unduly influence the consumption, such as automatic washing machines, a very high standard of living, or a large amount of entertaining.

In designing a septic tank consideration should be given to the rates at which sewage will enter the tank. The following table is reproduced from Recommended Minimum Requirements for Plumbing published by the National Bureau of Standards in 1929.

Fixture	Outlet 1 nominal dia in.	Trap & Waste in.	Rate gpm	Fixture unit or cu.ft./min.	Velocity in drain per sec. feet	Time req. to empty 2
Basin	1¼	1¼	7.5	1	1.9	12 sec.
Sink	1½	1½	11.3	1½	2.0	30 sec.
Bath tub	1½	1½	15.0	2	2.7	1½-2min.
[3]	2	2	26.3	3½	2.0	1-1 1/3min.
Laundry tub	1½	1½	22.5	3	4.0	20 sec. up 20 sec.for1
Common fixture with one trap	1½	1½	22.5	3	4.0	40 sec.for2
Water closets	3	3	45.1	6	2.0	6-10 sec.

1. Outlets from fixtures are commonly made one nominal size smaller than the trap for convenience in making slip-union joints, a practice that offers other advantages; hence the actual diameter is less than stated nominal values, varying from one-eighth to one-fourth inch.

2. Time for emptying the basin and sink are given for the full fixture 1½ and 6 gallons capacity, respectively. The time given for other fixtures gives a range that will vary with the capacity of the fixture and extent of filling.

3. No determinations were made with 2-inch bathtub outlets, and the values given represent an estimate to the nearest one-half fixture unit.

This table is based on experimental work and is presented in the report as approximately representing the rates of discharge of the common plumbing fixtures under conditions specified with relative values expressed in fixture units as well as rates of discharge. The fixture unit adopted, 7.5 gallons per minute, is approximately 1 cubic foot per minute. Through the use of the rates of discharge shown in this table, an estimate can be made of the rates to be expected at the entrance to a septic tank. This is an important factor to consider in the design of the inlet arrangement.

Few data are available concerning the per capita sewage flow from an individual house. Data from the Kansas State College study show an average per capita sewage flow from two farm homes to be 14.5 and 19.2 gallons per day. The maximum days occurred on Monday and Saturday, and the maximum months during the Summer. Conclusions given in the Illinois study state that where all of the house supply is discharged to the sewer and none is used for farm purposes, that the sewage flow is approximately equivalent to the water consumption.

Most state regulations recommend that the sewer line from the house to the septic tank be at least 4 in. in diameter of bell and spigot pipe with tight joints. In those cases where the sewer lines are within minimum distance from water supply sources, the sewer must usually be of cast iron pipe. A 1933 APHA committee reported that there is some tendency for tree and shrub roots to enter the cracks of sewer lines, and that the joints should be made of materials that will prevent roots from entering. Sulfur base compounds and copper rings have been used for this purpose.

Most States do not require that grease traps be used on septic tank installations for individual houses. Little information has been located concerning the use of such traps in other countries. Oothuizen in South Africa reported on a tank to treat only water closet wastes, and recommended that other wastes be discharged to a leaching cesspool. From the Victoria, Australia survey it appears that most tanks there treat only water closet and urinal wastes. However, no mention is made of the disposition of other wastes. In those cases where grease traps are used, most States recommend that they be installed in the kitchen drain as close as possible to the house.

Various types, shapes, and arrangements of septic tanks have been used

since this type of tank was first proposed by Mouras. Detention periods have varied from a few hours to several days in tanks of one and multiple chambers, of rectangular and circular plan, with and without sloping bottoms, and with various types and arrangements of inlet and outlet devices. In Germany, the so-called "fresh-water clarification tank" came into use during the 1920's. This type of tank afforded a detention period of from 1 to 2 hours, and was based on the Imhoff type tank. Later, in Germany and in Poland the trend was toward the use of the old fashioned septic tank with detention periods up to 20 days. The use of the small fresh water tanks has gradually declined. In the United States, septic tank design criteria have varied widely among the different organizations publishing information. In recent years the trend has been toward a standardization of design factors, based to a large extent on the work of the Joint Committee on Rural Sanitation.

In the United States, detention periods in septic tanks vary from 12 to 72 hours, with the average being approximately 24 hours. Recommendations by Sierp in Germany and Szniolis in Poland call for a detention period of 3 to 20 days, which is the longest period noted in the literature survey. Temple and Ganguli in India based tank capacities on the criteria of 2 cu. ft. per capita, while in Victoria, Australia the liquid capacity required is 300 plus 30 N Imperial Gallons (N being the number of persons). In Poland, Szniolis recommends a design capacity of 1 cu. m. per capita (264.2 gallons). In the United States, the usual practice is to provide for 24 hours detention with a sufficient additional capacity to allow sludge storage. The majority of the states prefer a liquid capacity of 500 gallons, though the recommendations vary from 300 to 1000 gallons.

The allowances to be made for the accumulation of sludge and scum are usually based on empirical estimates. Ganguli estimates that the average accumulation is 0.5 cu. ft. per person per year, while results of a survey of 35 tanks in California showed that the accumulation of sludge and scum in a rectangular tank was 1.38 cu. ft. per person per year. In the Illinois study, Lehmann found that the accumulation in the three farm tanks over a 2 year 8½ month period was 3.35 cu. ft. per person per year. The California State Health Dept. recommends an allowance of 20 gallons per person per year, and the 1942 Joint Committee report did likewise.

Little information on the amount of freeboard required is available except from the United States. The State requirements specify between 6 and 24 in. of freeboard, with the average being about 12 in. Some question has been raised as to the necessity for any freeboard, though no cases have been found where the tank has none.

In Poland the septic tank system is vented through the building plumbing stack and also at the end of each tile line, while the usual practice in the United States is to vent only through the plumbing stack. In England Ferguson recommended that the inlet pipe be vented.

Most of the articles reviewed favored the use of either submerged inlets or baffles to break up the influent velocity and similar devices for the outlet to prevent scum being carried to the absorption system. Various plumbing fittings such as elbows, tees, and U-bends are used to provide submerged inlets and outlets. Three States recommend no inlet device. Stewart at the University of Minnesota found that a tee with the open ends turned sideways, or a current breaker box provided the most satisfactory

inlet conditions.

Various types of partition walls and scum boards have been used to improve the operation of septic tanks, though none has been generally accepted. In Australia the Health Department warns against the use of chambers filled with stone, since they provide no treatment. Ganguli recommends the use of a grit chamber 1/6th to 1/8th the length of the tank. Marston and Okey and later Peterson at Iowa State College conducted experiments to develop a self-contained treatment plant which consisted of a septic tank, a sand filter and finally a trickling filter.

On the basis of the Illinois experiments, Lehmann et al recommended the use of a two compartment tank. Sierp and Ozniolis recommend the use of three chamber tanks regardless of whether they are rectangular or round in plan. Imhoff in Taschenbuch der Stadtenwasserung recommends the use of baffles in the tank presumably to effect compartmentation. Schreiber describes a tank which he developed of four chambers formed in a circular tank by fixed baffles. The first two chambers serve to remove the heavier solids and discharge the solids to a digestion chamber located below. The third and fourth chambers are used to remove the finer material. In the United States, most health authorities recommend the use of a single compartment tank, though six states favor a two chamber tank, while one recommends the use of a three compartment tank.

In the United States, all State regulations favor the use of a rectangular shaped septic tank. Only two States give specifications for round tanks. The usual ratio of length to width employed is between 2:1 and 3:1, and no State recommends a ratio greater than 3:1. The usual water depth employed is 4 ft., though this varies from 3 to 5 ft. In India, Temple recommended the

use of ratios of length to width of 6:1 or greater. Victoria, Australia regulations call for a ratio of length to width of 3:1, and a water depth of at least 3 ft. 6 in. Most foreign articles reviewed favored water depths of approximately 4 ft., though the minimum was 30 in.

Of the research projects conducted in the United States, none carried out any studies using round tanks, nor was any factual information relative to round tanks found in foreign literature. Round tanks are used in Poland, Germany, and India, though in Germany most of the round designs are the fresh-water type of tank.

All State regulations recommend that septic tanks be constructed of materials that are not subject to corrosion, such as concrete, cement blocks or brick. The latest Joint Committee Report specifies that where steel tanks are used they should be constructed of 12 gauge metal. Most foreign articles reviewed favored the use of concrete, brick, or stone tanks. In Poland, round tanks are constructed of unreinforced concrete rings of several standard diameters. The tank may then be made as deep as is desirable by the use of additional rings.

In Appendix B will be found several selected septic tank designs to show the variation in tank types encountered. Three state health department tanks are shown as well as samples of the "fresh-water" type of tank. In addition, a photostat of the first septic tank, and one of the first household septic tank in this country are included.

In Appendix C will be found a summary of commercial septic tanks for which information was received by this Station. Approximately 200 companies were solicited for information concerning tanks manufactured by their concern. A large percentage of replies were received, however, some companies had

stopped manufacturing tanks, some were temporarily out of this field, and some did not furnish sufficient information to include a listing of their tanks in this Appendix. The commercial tanks have been compared on the basis of standards in the Joint Committee Report with an allowance of 5% for compliance. Any tank below 500 gallons capacity was judged not in conformity with Joint Committee standards. Round tanks over 500 gallons capacity were also listed, together with their design statistics.

In the United States, dosing siphons are not generally used except for large installations. Where such siphons are used it is generally recommended that they be of such size as to fill the tile of the field one-half to three-quarters full at each discharge of the siphon. No information was available from foreign countries concerning the use of dosing siphons. The use of dosing siphons is desirable from the standpoint of utilization of all parts of the effluent disposal system. Sierp in Lebensmittel Chemie states that ground absorption of septic tank effluent can be improved by providing sufficient aeration, and that this can best be accomplished through the use of a dosing device.

The purpose of a distribution box is to distribute evenly the tank effluent to all lines of the tile field. The use of a distribution box is recommended in most State regulations. This box may also be used as an inspection manhole to determine if sludge particles are being carried to the tile field. It may also serve in connection with alteration of tile lines. All of the outlet lines from the distribution box must leave at the same elevation. A tank design in the New Zealand Journal of Agriculture showed a distribution box cast as an integral part of the tank structure. Szniolis stated that distribution boxes were not used in Poland.

Most information concerning the disposal of septic tank effluent is available from the United States. Some information from other countries is available, though it is very meager and quite indefinite. Except in special circumstances, the usual method of disposal of the effluent is by means of a subsurface tile disposal field with ground absorption of the effluent. This system is composed of one or more lines of drain tile laid in gravel about 18 in. below the ground surface. Most State regulations recommend the use of common 4 in. agricultural drain tile for constructing this system, and a few permit the use of V-shaped troughs of rot-resistant wood. The 1933 APHA Committee Report suggested the use of a 12 in. concrete pipe split lengthwise and laid on a bed of gravel. In addition to these materials, perforated fiber conduit, perforated bell and spigot tile pipe, and perforated concrete tile are available. Ordinary agricultural tile are usually laid on a grade of 2-4 in. per 100 ft., though the State regulations vary considerably. The maximum allowable grades vary from 1 to 12-5 in. per 100 ft. The tiles are usually laid with a spacing of $\frac{1}{8}$ to $\frac{1}{2}$ in., and this opening is covered with tar paper or in some cases pieces of galvanized metal. In South Carolina in a sandy area, it was found that the first 25 to 30 ft. of a tile line clogged quite rapidly when ordinary grades of 2-4 in./100 ft. were used. To alleviate this difficulty steep grades are used (12-18 in./100 ft.) in the first half of the tile lines.

The average minimum trench width recommended by the State regulations is 18 in., though these vary from 10 to 24 in. The tile is usually located about 18 to 24 in. below the ground surface. In one state the preferred depth of cover is 60 in., while in another it is 10 in. It is general practice to surround the tile with gravel. Recommendations as to the amount of gravel vary from 20 in. to a very small amount under the tile, and from none to 6 in.

over the tile. The Joint Committee report recommends that at least two lines of tile be used for a field, though only three States make this same recommendation. Nineteen States make recommendations concerning the length of individual tile lines, and these maximum lengths vary from 50 to 200 ft. with the average being approximately 100 ft. State regulations on the minimum spacing between tile lines vary from 3 to 10 ft. with the average being about 8 ft. The Joint Committee recommends that the spacing be at least three time the trench width with a minimum spacing of 6 ft.

It is the usual practice in this country to vent the septic tank system through the building plumbing stack with some aeration occuring through the soil. In Poland the usual practice is to vent through the plumbing stack, and also provide a vent at the end of each tile line. This same system is recommended by Sierp in Germany.

The amount of tile required to satisfactorily dispose of the effluent is the subject of the most variance in State regulations. For a detailed discussion of this, the reader is referred to Appendix A. Some States base their requirements on length of tile for a particular system, while others express it in feet of tile per person or bedroom. In addition, requirements are sometimes expressed in square feet of absorptive area, the assumption being that the area of the bottom of the trench is the effective absorptive area. Based on feet of tile per system, the recommendations vary from 70 to 500 ft. depending on the nature of the soil. Recommendations on a ft. per capita basis vary from 12 ft. to 100 ft. for soils of coarse sand or gravel to clay with some sand or gravel. In most cases the use of tile fields in clay soils is deemed unsatisfactory. The Joint Committee report recommends that tile field requirements be based on absorptive area determined by soil

percolation tests and using the maximum living capacity of the dwelling concerned.

The percolation test was originally proposed by Henry Ryon in an unofficial publication of the N. Y. State Department of Health. Since then it has been widely adopted. A detailed presentation of the data is given in Appendix A. The test is based on the absorption of water from a 12 in. square hole dug to the depth of the trench. The amount of tile or absorptive area required may then be determined from the chart after observing the time required for water to fall one inch in the hole. The percolation test values of the Joint Committee are similar to Ryon's, though they differ in the upper ranges, and omit the faster rates of percolation taking 2 min. per inch as the minimum rate. The absorptive areas in sq. ft. per bedroom recommended vary from 50 to 240 sq. ft. for 2 min. per inch and 60 min. per inch fall, respectively.

Most State regulations recommend the use of subsurface tile systems rather than seepage pits, however, such leaching cesspools for disposal of the tank effluent are permitted in most States. Oftentimes, they are used to supplement the tile disposal system, though they may be used as the only method of disposal. They are most often used where the surface soil is very tight and where a relatively porous soil underlies this. The Joint Committee report recommends that the capacity of a cesspool be at least equal to the capacity of the tank, and in tight soils at least twice the tank capacity. In most cases, the cesspools are lined with brick or stone.

Several States recommend that a subsurface sand filter be used in soils which will not readily absorb the effluent from an ordinary soil absorption system. With this type of disposal system, provisions must be available for disposing of the filter effluent to a natural water course. The distribution

tile is usually laid in 6 to 8 in. of gravel at about the same depth as the tile in a filter trench. Under this is located from 1 to 3 ft. of coarse sand, and the effluent is collected by another tile line laid in gravel. The usual depth of sand is about 24 in. The usual allowable rate for dosing these filters is approximately 1 gallon per sq. ft. per day. Some States express these requirements in sq. ft. per person. Two States require a minimum filter area of 300 sq. ft. In some cases the distribution tile are vented to the ground surface, and the filter may only be used in connection with a dosing siphon.

One State recommends that a chemical toilet or privy be used when impervious soils are encountered.

Various other types of secondary treatment have been used for septic tank effluent. In Poland, small trickling filters, or 30 minutes contact with a solution of calcium hypochlorite are often used where soil conditions are such that a subsurface tile field can not be used. Szniolis also mentioned the use of high pressure sprays which are used to spread the effluent over farming areas. Marston and Okey and later Peterson at Iowa State College designed a septic tank with a sand filter and trickling filter built as an integral unit. In Public Health Bulletin No. 101, Frank and Phynus describe a lath trickling filter, which they recommend for use in small installations in preference to stone filters. They state, however, that some form of distributing devise must be provided, and describe several types in this paper. Present practice in the United States usually recommends that these methods of secondary treatment be used only when it is impossible to secure treatment by soil absorption.

Based on reports from a group of plumbers in the Northern United States, it appears that freezing in septic tank systems does not occur as frequently as thought, and that systems are much shallower than recommended by the State regulations in these areas. Flood in New England stated that systems had been built there with 18 to 24 in. of cover, and they had operated satisfactorily for a period of years. A detailed summary of the plumber survey and other freezing aspects is given in a later section of this report.

The disposal of garbage through a septic tank system proposes many new considerations affecting septic tank design. Estimates based on a literature review show that the average per capita garbage production is approximately 0.65 lb. daily. This figure is subject to much variation however, and is affected by seasonal and geographical conditions. In designing septic tanks to take care of ground garbage, consideration must be given to increased quantities of sludge, scum, and grease, and to the effects of the increased solids loading on the effluent disposal system. A more detailed review of this situation is given in a later section of this report. The discharge of zeolite water softener regeneration wastes to a septic tank must be considered for those houses with such equipment. Opinions of various State health authorities show that with a tank of adequate size, the addition of regeneration wastes will not materially affect the proper operation of a septic tank.

Various proprietary materials are available for use in cleaning toilet bowls, sinks and clogged drains. Both acid and alkaline compounds are used for these purposes, and the continued use of such materials in large quantities is detrimental to the bacterial life of the septic tank. Tests conducted by consulting chemists for two of the largest manufacturers of these materials showed that when used in average amounts, these chemicals produced

no ill effects on septic action.

There are materials available which purport to increase, restore, or continue septic action in a septic tank. One product which was analyzed consisted of dried yeast, and sold for $1.00 for 4 ounces. Another product at $4.95 per gallon was thought to be a strong alkaline compound. Reports have been received that yeast has been used to a considerable extent, and many laymen are of the opinion that this material starts and keeps a septic tank working well. No factual information to support this supposition has been located. Several authors recommend the practice of seeding the tank with septic sludge both when a tank is placed in operation and after cleaning.

1. Collection and analysis of existing data (Cont)
   B. Select representative installations of various types for testing and gauging operations.

The first of a series of field sampling and gaging studies was started July 29th in the Cincinnati vicinity, with the installation of a sampling and gaging device on the effluent of a privately owned 900 gallon rectangular concrete single chamber septic tank serving a 3 bedroom, 4 person home. The tank is one approved by the Hamilton County Health Department, measures 41 in. x 73 in. x 69 in. water depth and is equipped with inlet and outlet tee fixtures. It is planned to construct another sampler to attempt influent sampling.

These data together with data being obtained at the Laboratory installations should be helpful toward evaluating and setting up performance criteria on septic tanks. Gaging statistics and flow patterns will be of immediate use in orienting the dosing patterns on the battery of tanks set up at the Laboratory and in connection with other experimental studies involving intermittent dosing on a household pattern.

2. Investigate existing installations of different sizes, shapes, types and materials, and determine efficiency of sedimentations, durability of materials, adequacy of sludge storage, and other basic characteristics.

In accordance with the decision reached at the N.H.A.-U.S.P.H.S. conference at Cincinnati in November, 1946 to examine existing installations in four areas, one each in the North and South Central sections of the country and the remaining two somewhat to the West and East, three engineers of the Water and Sanitation Investigations staff made field trips in January, contacting U.S.P.H.S. District Engineers, and the State and County Engineers in fourteen states from the Great Lakes to the Gulf, to locate

desirable areas for the field work. Criteria to desirable areas were an organized and active local agency with control over septic tank installations, a sizeable number of installations of various types, metered water supplies, records of installations, and cooperation.

After consideration of the reports of the contacts, practically all of the states approached having suggested one or more areas, and with the counsel of the engineers who made the contacts, the Dallas, Kansas City and Cook County areas were selected and field engineers, as they became available for assignment to this project, and after brief orientation at Cincinnati, were placed in these areas respectively in February, March and May. A three-man engineer-engineering aide-locally hired laborer team organized in the Dallas area in accordance with original plans was subsequently cut to two, an engineer-laborer team and the other areas similarly staffed with two man teams. With the assignment of additional engineers to the project teams were placed one each in the Cincinnati and St. Joseph County (South Bend locality) Indiana areas late in May, and a second team placed to operate in the Kansas City, Kansas area. Some difficulty was experienced by field engineers, particularly the earlier ones, in getting set up in the field due to time consumed in obtaining quarters, recruiting labor and in making the contacts necessary to orient themselves, consuming some 3 weeks on the average between departure from Cincinnati and initial inspection report.

The field examinations are being made in each area on the basis of a standard survey form and instructions. Sample instructions, survey forms and a reproduction of a completed survey of an installation are shown in Appendix D.

Reported inspections of individual systems through July, 1947 in the several areas are distributed as follows:

Distribution of Inspections by Area

Area No.	Location	Total Inspections through July, 1947
1	Dallas	15
2	Kansas City	58
3	Cook Co.	11
4	St. Joseph Co.	17
5	Cincinnati	9
		110

Distribution of Inspections by Tank Types

Tank Type	Conc.	Tile	Steel	Brick	Conc.Blk.	Stone	Total
Single vert. cyl.	1	-	32	2	-	-	35
Double " "	5	3	-	2	-	-	10
Triple " "	4	-	-	-	-	-	4
3 Comp.singlevert.cyl.	1	-	-	-	-	-	1
	11	3	32	4	-	-	50
Single hor. cyl.	1	1	-	-	-	-	2
Single comp. rect.	23	-	-	10	2	-	35
Double " "	4	-	-	3	-	1	8
Triple " "	5	-	-	9	1	-	15
	32	-	-	22	3	1	58
Grand Totals	44	4	32	26	3	1	110

A brief examination of the 110 field reports through July, 1947 follows. Although some preliminary observations are made the number of reports at hand is far too few to enable classification by types, sizes and various circumstances of loading and performance for comparison with sufficient numbers in the classes to iron out individual variation.

The ratio of resident persons per bedroom at 103 dwellings for which tanks were examined averaged close to 1 1/2 persons per bedroom with a distribution as follows:

Bed-rooms	Resident persons								Tot.
	1	2	3	4	5	6	7	8	
1	-	3	1	-	-	-	-	-	4
2	-	13	15	19	6	1	-	1	55
3	-	-	6	13	7	3	1	-	30
4	-	2	1	2	3	2	1	-	11
5	-	-	-	-	-	-	2	1	3
Tot.	-	18	23	34	16	6	4	2	103

Metered water supply records available at 39 installations indicated average water use of 42 gallons per capita per day in summer months and 37 gallons per capita per day in winter months. The distribution according to the number of persons per dwelling is as follows:

Pers./Dwg.	No. Dwgs.	S	W
2	4	67	52
3	8	48	41
4	15	39	37
5	6	32	29
6	2	24	20
7	3	40	30
8	1	32	23

There appears from this to be a decrease in per capita consumption as the number of residents per dwelling increases. However, the number of cases in each class is not sufficient to justify this as a conclusion.

Examination of field reports on 95 installations in the 5 areas as a whole indicate the bulk of laundering to be done at home at 70 installations or in 74 per cent of the cases. By areas, the percentages of installations at which the laundry is done at home are as follows: No. 1-31 per cent; 2-88 per cent; 3-91 per cent; 4-55 per cent; and 5-91 per cent. The low percentage in the No. 1 area (Dallas) brings up the question as to whether this reflects a general circumstance in the South and its bearing on design.

The distribution of wastes at 92 installations was as follows:

Wastes to Septic Tank	Distribution by Areas					Total	
	1	2	3	4	5	No.	Per cent
Bathroom, kitch., laund.	5	7	2	8	5	27	29
Bathroom, kitchen	9	16	1	5	4	35	37
Bathroom, laundry	0	3	2	0	0	5	5
Bathroom only	2	14	6	4	1	27	29
	16	40	11	17	10	94	100

Kitchen and laundry wastes not discharged through the septic tank were either passed by the tank to enter the tile system, or discharged to a separate tile system, or led to a surface watercourse(very infrequently on kitchen wastes). Kitchen wastes by-passing the tank to reenter the system at the tile field were passed through a grease trap in all cases, laundry wastes, in most, but not all, cases. Where discharge of such wastes was to a separate tile line kitchen wastes were trapped in more than half the cases and laundry wastes, in less than half. Laundry and kitchen (few) wastes to surface courses were untrapped.

Field men were instructed at the July 18 conference at Kansas City to select systems in which all wastes are discharged to the septic tank. This appears difficult to do in the Kansas City area and relocation in another area is being considered.

Trial analysis of reports on scum and sludge accumulations over a range of years indicate wide variation in individual cases and a broad spread of tank types, sizes, loading, age and waste arrangements to deal with. Some 54 installations on preliminary examination were accessible for adequate measurement and sufficiently complete and serviceable structurally to contribute to a basis for analysis. These break down for analysis into 4 waste distribution classes, 6 depth ranges at ½ foot intervals, 7 broad tank types,

14 ages and capacities ranging from 35 to 527 gallons per capita. The trial indicated that individual variation is too great to make comparisons with the few results yet available. Taken as a whole there appears to be a rough indication that the apparent increase in scum and sludge volume progresses at a declining rate with time. The overall results for the 54 cases, regardless of tank type, capacity, load or waste distribution follow. A rough trend is indicated in the range 1 through 6 years taking into account the number of cases represented and individual variation. With additional inspections, screening on the basis of design and loading characteristics will probably increase some of the values shown. The overall results:

Number of years accumulation represented	Number of installations	Per capita total accum. in cu. ft. divided by time in years
1	6	2.50
1½	2	2.89
2	6	2.22
3	4	1.57
3½	1	0.73
4	3	1.56
5	8	1.35
6	13	1.16
7	5	1.38
9	1	1.28
11	1	2.55
12	2	2.07
13	1	2.12
21	1	1.42

Preliminary examination of tank operation observations bring up the possible successful operation of a number of tanks at liquid depths less than 48 inches, chiefly single rectangular tanks and compartmented rectangular and round shapes. These, as well as those of greater depth, will be examined in the light of the absorption field results on the basis of the percolation test and soil analyses, which have not yet been completed. A brief examination of tile field data on the basis of field observations is presented later on.

No garbage grinder installations have yet been encountered in the present field survey areas. Contact has been made with General Electric Co. and a meeting with a representative is expected shortly to obtain the locations of grinders on septic tank installations over the country, following which an attempt will be made to examine some of such systems. There are estimated to be about 50,000 grinders installed in this country, presumably in sewered areas as well as those having private sewage disposal systems.

A few installations at which household zeolite water softeners were installed were examined. The brine wastes were discharged to a separate tile system, except in one case, in which they went to the septic tank. The particular system was flooded due to excessive rains this spring but had no previous serious difficulty in the reported history.

Effluent sampling started in the Dallas area in April was dropped because of the time involved for field personnel in that area, the lack of advance work at Cincinnati to indicate the value of grab sampling and the greater need for the chemist at Cincinnati. If grab sampling proves to be of value, upon investigation at Cincinnati, effort will again be made to sample, possibly through arrangement with local laboratories and personnel.

Inspectors' observations of the structural state of tanks with respect to deterioration indicate concrete condition to be good on 14 concrete tanks ranging from 2 to 21 years service, and fair on 2 aged 8 and 22 years; brick in good condition on 9 brick walled tanks ranging from 3 to 18 years in age, fair (bricks loose) on an 11 year old tank and poor on one more-than-40 year old tank; one each tile and concrete block tanks were in good physical condition at 4 and 5 years respectively. Metal tanks ran mostly from observable corrosion to failure of baffles above the water line, about 16 tanks aged 5

to 17 years falling in this group, and 6 aged 1 to 8 years were in good condition. This all refers to corrosion inside the tanks. There is a little information indicating corrosion to progress more rapidly above the water line than below.

The National Bureau of Standards recently inquired about the character of septic tank contents in connection with proposed corrosion work. This project offered to cooperate in providing analytical data on tank contents, condensate, etc. as soon as it could be procured and also offered bench space at Cincinnati for a technician if it were deemed advantageous to work close to sources of septic sewage and to place specimens in this locality. A few drops of condensate collected from two of the Laboratory tanks indicated pH's of 6.6 and 6.8 respectively. Tank effluents from the field sampling in Dallas indicated pH's of 7.2 to 7.8 on six installations, 6.8 on another. Tank effluents at the Laboratory run from 7.2 to 7.5.

Costs of cleaning septic tanks are available in a few cases from the reports. These indicate of $35 to $45 in the Kansas City area, $35 in the Cook County area, $25 to $30 in St. Joseph County, Indiana, $20 per ton in Cincinnati vicinity, and $33 and $35 in the Dallas area.

Two general faults prominent in the minds of the inspectors as a result of their close contact with systems thus far are poor construction and the lack of information on location of facilities and absence of maintenance instructions for the householder.

Reports containing sufficient information to allow an analysis of tile field conditions were separated into two groups; those where the field was operating satisfactorily, and those in which trouble was experienced. The

total number of reports used was 51, and of these fields 30 were operating satisfactorily. Thus, approximately 40% were causing or had caused trouble. The commonest criterion used in determining the status of a field was whether or not seepage to the ground surface occurred.

Of the 30 tile fields which were operating satisfactorily, 2 were constructed with no gravel surrounding the tile. One of these systems had been in use since February 1946, and the other since 1935. The one installed in 1935 had some additional tile installed in 1943. The total length of tile in this field was 125 ft. for a family of 5, or 25 ft. per capita. The one installed in 1946 had 19 ft. per capita.

In the 28 fields having gravel around the tile, the per capita absorptive areas varied from 3.67 to 103 sq. ft. The average absorptive area for these 28 fields was 49.2 sq. ft. per capita. The tank with the minimum area had a total of 22 square feet of absorptive area to serve a family of 6 persons. The system had been in service for 5 years, was located in a clay soil, and the occupants reported no trouble when questioned by the Field Engineer.

Analyses of the soil samples collected during these inspections has not been completed. Consequently, no attempt has been made to correlate the length of life of a field with the soil characteristics. The soil descriptions from visual observations are not accurate, so these have not been used.

Review of the accomplishments in the field examination of existing systems indicate a need for areas in which detailed records and effective control over construction date back to the less recent installations and enable examinations to be made through selection in advance and with some assurance that the examination will not have to be abandoned because of a construction fault such as missing outlet scum retention device, a solid tank top without access man-

hole or an inaccessible compartment.

A second consideration is the comparative value of the complete field examination as an immediate requirement in view of the cost and time required, and the consequent reduction in the number of tank examinations possible with limited personnel in a given time, bearing in mind that the study is entirely dependent on an analysis of thescum and sludge accumulation figures from the field for conclusions. The possibility arises also of the use of sludge and scum accumulations as an overall measure of the efficiency of particular tank shapes and sizes as a class.

To meet the shortcomingsof field areas to enable greater and more assured selectivity and productiveness, all U.S.P.H.S. Districts have been invited to assist by contacting all States in an effort to find areas in which such circumstances may exist. Many areas have control and records of recent origin whereas the most benefit to this study comes from systems which have been in operation for some time.

As to the second consideration, that of speeding up the rate of tank examinations, the field men were instructed at a conference at Kansas City, July, 18, to reorient their survey methods sufficiently to make the complete examination of tank and tile field on every fifth installation on the average and to limit the remaining four to tank, and tank and tile field history without examination of the latter. This will provide better selectivity on tile field examinations and increase the rate of tank report return (the tank examination type of report progresses at a rate of better than one a day per two-man team as against one complete examination every two days as the fastest average rate made thus far).

Meanwhile research at the Laboratory on soil clogging, soil analysis, the percolation test, and the tile line work, should provide better tools and ground work for a later direct attack on any absorption field examination necessary in the field.

3. Conduct such short term testing and research as may be possible and desirable to substantiate such items as efficiency of sedimentation, adequacy of sludge storage, capacity, size, shape, durability of materials and other comparable characteristics of commercial septic tanks.

Septic Tank

In order to compare the performance of commercial septic tanks, representing common basic shapes in use, plans were made for building or installing several tanks at one location. The site selected for the study had to be so situated that an adequate quantity of reasonably normal fresh sewage would be available at most times. Insofar as possible, the sewage should be comparable to that discharging from the average household unit.

In a previous study of septic tank operation (Illinois study), grab samples were collected every sixth day for physical and chemical analyses. In the present study, raw sewage and effluent samples were collected at each feed and discharge, composited, and then examined in the laboratory. Thus, a continuous record of the materials added to or removed from the individual tanks was obtained and the differences in tank operation noted more directly.

Several possible sites were considered in the Cincinnati area before plans were finalized for locating the experimental phase of the project in the greenhouse at the Water and Sanitation Investigations Station, U. S. Public Health Service. The site selected has several advantages, namely: a relatively large quantity of fresh domestic sewage supplied to the Station through a connection with the municipal sewer; proximity to laboratory facilities, thus simplifying sample collection and storage; the presence of fairly suitable housing facilities for the project; the presence of caretaker on property at all

times and the presence of all necessary utilities, shops and special maintenance personnel. The disadvantages are: intermittent discharge of acid wastes by a single industrial plant, and the dilution of sewage flows following periods of rainfall because the Station sewer is connected to a combined sewer.

The present operating installation includes eight septic tanks: Joint Committee, 2000-gallon concrete; and one each of the following, all approximately 500 gallons capacity, vertical cylindrical, steel; horizontal cylindrical, steel; flat-sided, semi-circular end, steel; oval, concrete; two stacks 35 inch tile in series, four stacks 24 inch tile in series, and a Joint Committee tank.

The tanks described above are fed in series several times a day (see below) from a dosing tank filled with pumped fresh raw sewage.

At the start (June 9, 1947), septic tank sludge was obtained from the field for seed purposes, and all tanks were seeded at the rate of ten per cent of their volumetric capacity. Thus, the 2000-gallon tank received 200 gallons of seed material and all other tanks received 50 gallons. In the case of the multi-chambered tanks, each compartment received an aliquot portion of the entire volume of seed, that is, 25 gallons of seed material were added to each of the two 36-inch diameter compartments, and 12½ gallons to each of the four 24-inch diameter compartments.

Each tank is dosed intermittently throughout the day. At present, eight feeds totaling 500 gallons per tank throughout a period of 17 hours constitute the dosing cycle. The time and quantity of each feed is given in Table I, and was determined from a study of individual water use data collected by the

Station engineers. The total volume of flow (500 gallons per tank per day) was selected to give a theoretical detention time of 24 hours in each of the 500-gallon tanks, and 4 days in the 2000-gallon tank.

Three men working a forty-hour week at staggered hours, from 6:30 a.m. to 3:00 p.m. and 3:00 p.m. to 11:30 p.m. feed the units seven days a week, collect the necessary data, and composite the samples. Each man works four days on one shift, has two days off, and then four days on the other shift.

The following information is collected at each feeding; time of feed, volume of feed, air temperature, raw sewage temperature, height of effluent in collecting tanks, and temperature of the effluent. A copy of the data form is included in the Appendix. The volume of effluent is taken from calibration charts determined for each series of collecting tanks (two 55-gallon drums), and recorded along with the results of the chemical analyses. Chemical data recorded include total solids, total solids ash and volatile, suspended solids, suspended solids ash and volatile, dissolved solids, dissolved solids ash and volatile, pH, and at times the alkalinity. The duration of each feed is also noted so that comparisons of the rates of feed may be made.

Table I - Feed Schedule - Septic Tanks

Time of day	Amount of Feed in Gallons per Tank
7:00 a.m.	65
9:00 a.m.	60
11:00 a.m.	50
1:30 p.m.	65
4:30 p.m.	70
7:00 p.m.	75
9:30 p.m.	65
11:00 p.m.*	50

*This time was changed to 10:30 p.m. on June 23, 1947

The results reported below are for one particular dosage rate (500 gallons per tank per day) which is higher than that which would normally occur in practice. Therefore, it may be said that all the tanks are overloaded with the exception of the 2000-gallon tank. Lower rates of feed would in all probability indicate higher efficiencies in solids removals. It must be remembered too, that tank operation is a function of the raw sewage added and the results herein expressed are valid for the type of sewage that was fed (typical analyses given below).

The data presented reflect comparative tank performance under only one of a range of experimental runs under various operating and loading circumstances. Subsequent runs may or may not bear out the comparisons indicated, and while the data are considered very informative in the light of current information on septic tank design, and very valuable in orienting this and other phases of the study, caution is urged against generalization or release of the information at this stage.

A week was considered to be a satisfactory period of operation for comparison of the results. All data collected are summarized on a weekly basis and efficiencies are computed for each week of operation and for the total period of operation. Laboratory results were tabulated daily and from these the following quantities were computed: total solids in pounds, total volatile solids in pounds, suspended solids in pounds, and total suspended solids in pounds. Summation of these permits estimates of weekly removals of total and suspended solids by each tank and provides a means of computing tank efficiencies. Efficiencies were computed on the basis of the removals in the 500-gallon Joint Committee Tank, but since this tank operated so erratically, more suitable comparisons were possible using the 2000-gallon

Joint Committee tank as a base.

Tables II and III give the weekly and cumulative efficiencies of each tank, respectively.

Sludge and scum measurements were made at the end of each week of operation. Sludge sounding and scum measuring rods similar to the type developed for field use were utilized and are described elsewhere. Scum measurements were made at the influent and effluent ends of the tanks and sludge measurements were made at several points in all tanks. The number of measuring points selected was dependent upon the size and the shape of the tank.

The amounts of scum and sludge measured are given in Tables IV and V, respectively. It will be noted that there has been no scum in the 2000-gallon Joint Committee tank. Chemical examination of the total solids and volatile contents of the scums have been made on alternate weeks, and the results are given in Table VI. No sludge analyses have been made to date. Equipment is being developed for collecting sludge samples for analysis. Sludge volumes are only relative, since no information is available as yet on the degree of compactness of the sludge.

Table II - Weekly Efficiencies Based on Solids Removal

Total Solids

Date	June 17-23		June 24-30		July 1-7		July 8-14		July 15-21		July 22-28		July 29 - Aug. 4	
	(2)	(3)	(2)	(3)	(2)	(3)	(2)	(3)	(2)	(3)	(2)	(3)	(2)	(3)
Tank 1	181.8	100	1744.0	100	245.0	100	164.6	100	370.1	100	298.5	100	256.7	100
2	124.1	68.3	917.3	52.6	94.0	38.3	66.6	40.5	196.1	53.0	133.7	44.8	110.0	42.9
3	142.1	78.3	1804.6	103.5	225.0	91.8	135.8	83.2	371.0	100.2	329.9	110.5	191.2	74.5
4	160.6	88.5	1901.0	109.0	173.0	70.6	109.4	66.4	390.2	105.4	310.4	104.0	188.1	73.3
5	141.8	78.0	-	-	58.5	23.8	114.7	69.6	93.9	25.4	279.7	93.7	62.5	24.3
6	37.8	20.8	165.5	9.5	52.7	21.5	89.8	54.5	190.2	51.4	7.6	2.5	90.1	35.1
7	100	55.1	100	5.7	100	40.8	100	60.7	100	27.0	100	33.5	100	39.0
8	86.0	47.3	949.6	54.5	180.4	73.6	135.8	82.5	190.8	51.5	153.9	51.5	145.1	56.5

Suspended Solids

Tank 1	177.4	100	-	100	245	100	199.2	100	1333.3	100	277.1	100	256.8	100
2	101.6	57.3	-	67.7	111.0	45.3	65.0	32.6	506.1	38.0	146.2	52.8	127.9	49.8
3	92.4	52.1	-	107.8	251.0	102.3	201.6	101.3	1523.4	114.3	336.4	121.4	249.6	97.3
4	107.2	60.5	-	110.4	168.2	68.7	116.5	58.5	1380.2	103.5	300.6	108.5	237.9	92.6
5	146.3	82.5	-	-	29.0	9.3	126.1	63.3	-	-	267.0	96.4	53.0	20.7
6	-	-	-	3.8	35.2	14.4	84.2	42.2	544.2	40.8	24.2	8.7	99.3	38.7
7	100	56.4	-	0	100	40.7	100	50.2	100	7.5	100	36.1	100	38.9
8	14.8	8.3	-	62.5	211.0	86.1	185.1	92.9	600.0	45.0	179.9	64.9	185.5	72.2

(1) Tank identification (Dwgs. and Dimensions shown in Appendix F): 1) 2000-gallon Joint Committee; 2) rounded end steel; 3) 36" dia. 2 chambered tile; 4) 24"dia. 4 chambered tile; 5) oval, concrete; 6) vertical cylindrical, steel; 7) 500-gallon Joint Committee and 8) horizontal cylindrical, steel.

(2) Percent removals based on weekly removal in 500-gallon Joint Committee tank.
(3) Percent removals based on weekly removal in 2000-gallon Joint Committee tank.

Table III - Cumulative Efficiencies Based on Solids Removal

Total Solids (2)

Date	6/17-6/23	6/17-6/30	6/17-7/7	6/17-7/14	6/17-7/21	6/17-7/28	6/17-8/4
(1) Tank 1	100	100	100	100	100	100	100
2	68.3	60.6	52.1	49.4	50.0	49.4	48.3
3	78.3	90.5	91.0	89.2	91.1	93.4	90.1
4	88.5	98.4	87.8	82.9	86.7	88.7	86.1
5	78.0	39.9	33.7	41.3	39.1	45.6	41.9
6	20.8	15.5	17.8	26.2	30.5	27.2	28.5
7	55.1	30.9	34.7	40.7	38.4	37.8	38.0
8	47.3	50.8	59.5	64.8	62.6	61.3	60.4
Suspended Solids (2)							
Tank 1	100	100	100	100	100	100	100
2	57.3	63.5	55.8	50.3	48.2	48.9	49.0
3	52.1	84.8	92.2	94.4	97.7	101.1	100.5
4	60.5	89.8	80.9	75.5	80.2	84.3	85.6
5	82.5	34.0	24.7	33.9	28.3	38.2	35.4
6	0	2.2	7.4	15.7	19.9	18.2	21.5
7	56.4	23.3	30.6	35.3	30.7	31.5	32.7
8	8.3	40.1	59.5	67.5	63.8	64.0	65.3

(1) See (1) in Table II

(2) Percent removal based on cumulative removals in 200-gallon Joint Committee tank.

Table IV - Scum Quantities - cubic feet

Tank (1)	June 24	July 1	July 8	July 15	July 22	July 24	August 5
1	-	-	-	-	-	-	-
2	0.75	1.25	1.50	1.50	1.05	0.60	0.60
3 total	-	0.50+	0.02+	0.08	1.31	2.23	2.04
3 a (2)	-	-	-	0.02	1.29	2.17	1.61
3 b (2)	-	0.50	0.02	0.06	0.02	0.06	0.43
4 total	0.26+	0.47+	1.19	1.56	1.74	1.13	1.10
4 a (2)	-	tr.	0.87	1.15	1.14	0.93	0.72
4 b (2)	0.13	0.18	0.30	0.38	0.58	0.08	0.21
4 c (2)	0.13	0.27	0.01	0.02	0.01	0.11	0.16
4 d (2)	tr.	0.02	0.01	0.01	0.01	0.01	0.01
5	0.94	1.27	2.39	1.27	0.05	0.37	0.50
6	1.57	1.57	1.21	1.44	0.49	0.31	0.49
7	1.48	1.42	1.28	1.63	0.12	0.47	0.47
8	0.61	1.22	1.25	1.07	0.91	0.61	0.61

(1) See tank descriptions Table II

(2) Respective chambers of multichambered tanks.

Table V - Sludge Quantities - cubic feet

Tank (1)	June 24	July 1	July 8	July 22	July 29	August 5	
1	14.98	15.88	9.39	16.16	15.80	14.80	
2	1.99	1.74	1.44	1.44	1.93	2.02	
3 total	2.36 +	3.85 +	5.16	4.00	4.99	3.89	
3 a (2)	2.36	3.85	4.54	3.38	4.00	3.27	
3 b (2)	0.71	0.62	0.62	0.62	0.99	0.62	
4 total	5.19	5.73	4.37	3.40	4.88	5.73	
4 a (2)	1.78	2.70	2.38	2.06	3.57	4.52	
4 b (2)	0.88	0.65	0.74	0.32	0.38	0.51	
4 c (2)	1.04	1.26	0.32	0.32	0.32	0.32	
4 d (2)	1.49	1.12	0.93	0.70	0.61	0.38	
5	3.10	3.08	1.54	3.76	1.88	2.88	
6	1.48	1.79	1.35	2.20	1.93	1.62	
7	2.88	1.96	1.72	3.22	2.52	2.67	
8	0.67	0.34	0.36	0.91	1.46	1.58	

(1) See tank descriptions Table II

(2) Respective chambers of multichambered tanks.

Table VI - Scum Solids Analyses

Tank (1)	Total Solids - %				Volatile Solids - %			
	6/25	7/8	7/22	8/5	6/25	7/8	7/22	8/5
1	9.9	-	-	-	65.8	-	-	-
2	9.7	12.7	12.6	11.6	61.3	57.0	52.9	56.0
3 a	8.7	8.1	9.7	12.5	59.8	62.1	66.0	60.5
4 a (2)	9.6	12.0	15.4	17.4	60.1	66.2	65.1	61.4
4 b (2)		11.1				58.6		
5	9.7	13.2	8.7	11.6	59.8	56.3	59.7	58.7
6	10.6	12.6	9.9	11.9	58.6	56.3	56.0	55.2
7	11.3	13.2	8.2	10.3	55.2	57.0	53.9	56.6
8	9.9	14.0	11.9	11.4	60.4	54.6	53.0	53.3

(1) See tank descriptions Table II

(2) Respective chambers of multichambered tanks.

The operating tank data collected to date indicate that under the circumstances of this particular run:

(a) The two multichambered tanks of 500 gallons capacity gave as good, and at times even better, removals in total and suspended solids as those obtained with the 2000-gallon single chamber tank receiving the same dosage, 500 gallons per day.

(b) The two multichambered tanks of 500 gallons capacity were much superior in removal of total solids and suspended solids in comparison with the five 500-gallon single chambered tanks.

(c) The horizontal cylindrical tank produced the best effluent of the five 500-gallon single chamber tanks.

(d) The vertical cylindrical steel tank showed the lowest removal in suspended and total solids.

(e) The remaining three 500-gallon single chambered tanks had approximately the same efficiency.

Future Work Relative to Tank Shapes

As the present study indicates marked advantages of multichambered over single-chambered tanks, plans are under way for the construction of two- and three-chambered tanks of either rectangular or circular cross section.

Additional studies in the wooden flume mentioned above will be made with tanks of varying depths and length to width ratios to study the effect of these on suspended and total solids removals.

It is hoped that studies will be made of each of the above-mentioned structural changes in the presence of sludge and scum in varying amounts

as well as in the absence of either scum or sludge. In other words, what effect, beneficial or otherwise, does the depth of sludge or scum have on removal efficiencies?

Inlet and Outlet Studies

A large wooden flume 15 feet long, and four feet deep with two channels each three feet wide will be used for making studies on the effect of inlet and outlet structures on solids removal efficiencies. Two Joint Committee dimension 500-gallon tanks (6 x 3 x 4 feet) are to be studied at present. Both tanks have tile tee inlets. One tank has a tile tee outlet and the other has an effluent outlet weir with a baffle approximately 6 inches in front of it extending to the depth of the outlet tee in the former tank. Inlet weir devices and other inlet distribution devices will be studied, including the effect of adding raw sewage near the bottom of the tank or below the top of the sludge level.

Sewage

Character - The sewage used for the experimental work was analyzed during the period March 31 to April 30, 1947, and the results obtained are given in Table VIII. Solids determinations from June 10 to August 4, 1947, are given in Table IX.

The data in Table IX are more reliable and representative since they are based on the results of composite samples, whereas those in Table VIII are based on grab samples collected at various times during successive days.

Table VIII - Raw Sewage Characteristics

Determination	Number	Parts per million		
		Average	Maximum	Minimum
Total solids	21	1257	1978	786
Ash	21	683	1008	374
Volatile	21	574	1141	341
Suspended solids	21	315	744	153
Ash	20	101	194	41
Volatile	20	211	601	43
5-day B.O.D.	17	272	714	78
Oxygen consumed	19	197	411	57
Ammonia N	21	15	28	7
Organic nitrogen	19	58	99	21
Alkalinity	20	201	485	22
pH	21	7.1	7.9	2.2

Table IX - Raw Sewage Characteristics

Determination	Number	Parts per million		
		Average	Maximum	Minimum
Total solids	56	1003	1276	753
Ash	56	509	659	386
Volatile	56	494	709	242
Suspended solids	56	353	637	94
Ash	56	77	152	8
Volatile	56	276	559	86
Dissolved solids	56	650	1182	363
Ash	56	432	617	340
Volatile	55	218	565	2
Alkalinity	20	240	285	181
pH	56	7.5	7.7	5.5

Domestic Sewage Check - In order to obtain information on the characteristics of a normal household sewage for comparison with the Station sewage used in the project, it is planned to collect representative composite samples from a sewer line serving seven homes in a suburb of Cincinnati. These homes are connected to a separate sewer receiving no storm water nor other wastes.

Analytical Methods -

(a) Colloids. For the tentative determination of colloids in sewage and septic tank effluents, the following procedure has been proposed. The method is based on the fact that colloids are adsorbed from suspension by a suitable adsorbing substance, which in this case was activated carbon. Other substances may also be adsorbed by the activated carbon. However, this procedure appears to offer more promise than any other method suitable for routine work in this laboratory.

A Gooch crucible was prepared with an asbestos mat, dried, and ignited in the usual manner. A suspension of activated carbon in distilled water was then poured through the crucible to form a thin layer, 2-3 mm. in thickness, on the surface of the asbestos mat. The prepared crucible was dried for one hour at 105°C., then weighed.

The filtrate obtained from the suspended solids determination was removed quantitatively from the filter flask and poured through the prepared crucible. It was washed with distilled water, dried at 105°C. for one hour and then weighed. The difference was reported as ppm. colloids. The filtrate obtained was water-clear and colorless.

Preliminary determinations on two tanks gave results of 11 and 4 ppm., respectively.

The activated carbon used was from a sample of Dow "Cliff-char-R-fine activated carbon." An attempt was made to determine colloids by means of silica gel, but the results were negative. Additional work is planned with the activated carbon method described above.

(b) Oxygen Consumed Test. The oxidixable substances in sewages have been estimated by reduction using a hot mixture of potassium dichromate and sulfuric acid. After a suitable boiling period in a refluxing condenser

system, the dichromate consumed is determined by analytical procedure. The oxidation is calculated in ppm. of oxygen. Preliminary studies would indicate that the oxygen consumed value decreases as the detention period of the sewage is increased in experimental holding tanks. This is also true of sewage percolated through sand filters.

Soil Absorption Studies

Percolation Test, Soil Analysis - Soil percolation tests have been made in the Cincinnati area on various soil types, using the standard one-foot-square percolation test, a one-foot-square confined box, and a ten-inch-diameter cylinder 18 inches long. These preliminary studies indicated that after correction for the greater seepage area in the unconfined test, the results obtained by all methods were similar. This led to the adoption of the 10-inch-diameter cylinder for making percolation tests in the field along with the standard unconfined test. It is hoped to correlate the results of the field percolation tests with soil characteristics. For this reason mechanical analyses (sieve and hydrometer), liquid limit and plastic limit tests are being run on samples submitted from field parties from the pits in which percolation tests are run. About fifty mechanical analyses determinations have been made to date, along with moisture content determinations. Nothing has been done on the liquid limits because apparatus needed for making the test has not been received.

An attempt is being made to correlate the coefficient of permeability to the percolation test in the field. To determine this the coefficient of permeability is computed for the test in place in terms of the thickness of the layer through which percolation takes place. The soil sample is then removed with approximately three to four inches of soil still in

place in the bottom of the percolation cylinder and the test is repeated, and the true coefficient of permeability is computed for the soil in question. From a study of the two results it may be possible to compute the effective depth of percolation. For dense soils it will be necessary to construct a variable head permeameter, since the amount of percolation is very small.

Clogging Characteristics - Samples of sewage after 24 hours' settling were passed through a three-inch diameter glass filter filled with 12 inches of sand at a dosage rate varying from 1260 to 4600 ml. per day. During the period March 31 to April 30, 86.21 liters of settled sewage passed through the filter. Assuming a maximum loading of 5.3 gallons per square foot per day (corresponding to a percolation test result of one inch fall per minute for seepage pits), this would be equivalent to operating the unit for approximately 2.6 years. The filter clogged several days later. The long period of operation may be due in part to the fact that the filter was operated intermittently; dosing for 4 days and resting for 3 days.

A summary of the laboratory data obtained in conjunction with the above study is given in Table X.

Table X - Summary of Laboratory Data - Filtration Study

Test	Raw			Settled		Filtered	
	Average p.p.m.	Max.	Min. p.p.m.	p.p.m.	% red.	p.p.m.	% red.
Total solids	1227	1978	786	850	30.7	805	34.4
Total volatile	510	1141	341	315	38.2	298	42.7
Total ash	717	902	374	535	25.4	606	15.5
Suspended solids	315	744	153	55	82.6	25	92.0
Suspended volatile	201	452	43	43	78.6	19	90.6
Suspended ash	114	168	41	12	89.5	6	94.7
B.O.D.	278	714	78	137	50.7	96	65.5
Oxygen consumed	197	411	57	109	44.7	63	68.1
Nitrogen	58	99	21	45	22.4	42	27.6
Ammonia	15	28	7	28	-	28	-
pH	7.1	7.9	2.2	7.2	-	7.3	-
Alkalinity	20.1	485	22	226	-	222	-

Tests on 19 samples of raw sewage indicated a total solids content of 1227 ppm. and a suspended solids content of 315 ppm. Storage for 24 hours, with quiescent settling, reduced these values to 850 and 55 ppm. respectively. Filtration lowered these values to 805 and 26 ppm. respectively. This corresponded to a reduction of 30.7 and 34.4 per cent in the total solids after settling and filtration, respectively, and 82.6 and 92.0 per cent in the suspended solids, respectively.

It is proposed to carry this study further, using sewages subjected to varying settling periods (or detention times) and passing them through filters of the type mentioned above to determine the effect of detention time on clogging of soils. The second phase of the study will involve the addition of sewages to soils having various characteristics (Hazen's effective size and uniformity coefficient for sands, liquid limit and plastic limit for other soils), to determine the effect of type of soil on clogging.

Grades, Joint Spacing - The study of the behavior of fluids flowing through the open joints in a tile field under various conditions of joint size, slope of tile line, volume of fluid, etc., was initiated.

A stand long enough to accommodate 10 feet of regular 4-inch field tile was set up in such a way that effluent could be collected at each joint. It is also possible to vary the slope.

To date, 67 runs have been made at a slope of 0.00 per cent, and flow rates varying from 1.15 to 17.1 gallons per minute. The amount of seepage was found to be a function of the joint spacing. In the present study the tiles were butted end to end. Even with this, invert spaces varied from 0.3 to 5.0 mm. It is hoped to correlate discharge rates through the joint opening with the size of opening.

A soil column was designed and is in the process of assembly. It is intended that a synthetic sewage medium will be run through columns composed of various soil types. The medium will be run through sterile, as a control, and may also be seeded with given pure cultures or seeded with sewage or septic tank effluent. In this manner the rate of flow (and the rate of clogging) under a variety of conditions may be studied.

Specimens of soils from the vicinity of septic tank tile fields were plated out on bacteriological media and fourteen bacterial strains were

isolated and examined for microscopic, colony, and biochemical characteristics.

In connection with preliminary work on the soil clogging characteristics of septic tank effluents, total bacteriological counts and coliform determinations have been made on the raw sewage and the tank effluent composite samples. The geometric means and the per cent reduction as compared to the numbers of organisms initially present in the raw sewage are summarized in Table VII. These results show a removal of 70 per cent or better for all tanks, with the best removals in Tank 1 which has a theoretical detention time of 4 days, and Tank 4 which is the four-chambered septic tank with a theoretical detention time of one day.

Coliforms are not reduced in the same proportion, as the results indicate that in four tanks having a detention time of approximately one day the removals varied from 29 to 62.6 per cent, whereas Tank 1 with a theoretical detention time of 4 days showed a removal of 84 per cent.

Additional data will be required before firm conclusions may be drawn from the above data. As the table indicates, reduction in total number of organisms was the same for the 2,000-gallon tank as the four-compartment installation and there was little difference between the lower reductions of the other tanks. The greatest reduction in coliform organisms occurred in the 2,000-gallon tank, with the other tanks varying from 29.0 to 62.6 per cent.

No anaerobic counts were made.

Table VII -Bacteriological Results*

Tank No.	Total count** 37° - 24 hrs.	% Reduction***	Coliform 37° (presumptive)	% Reduction***
Raw	6.29×10^6	-	3.80×10^5	-
1	1.16×10^6	81.5	0.65×10^5	84.0
2	1.84×10^6	70.8	1.73×10^5	54.5
3	1.73×10^6	72.5	2.00×10^5	47.4
4	1.16×10^6	81.5	1.64×10^5	56.9
5	1.49×10^6	76.3	1.42×10^5	62.6
6	1.87×10^6	70.2	2.74×10^5	29.0
7	1.88×10^6	70.1	1.90×10^5	50.0
8	1.76×10^6	72.0	1.44×10^5	62.1

* Geometrical mean, period July 14 to August 6, 1947.
** Agar 37°C. for 24 hours. 48-hour counts were reported after July 22.
*** Based on numbers of organisms in the raw sewage sample.

Garbage

A 500-gallon Joint Committee tank will be added to the present series of tanks under observation (see above), which will receive, in addition to the normal load of raw sewage, an amount of garbage equivalent to that resulting from a family of four per day. A comparison of the results obtained in operating this tank with the results obtained from the operation of the Joint Committee tank receiving only sewage, will indicate what effect the addition of this quantity of garbage may have had on the operation of the septic tank.

Household Zeolite Softening

To determine the effect of the addition of quantities of regenerating liquor to septic tanks serving homes equipped with softening units, studies were initiated on a laboratory scale wherein calcium, magnesium and sodium salts were added to seeded digestion flasks. Preliminary results indicated that subtoxic doses were actually beneficial in that the amount of gas produced (using gas production as the measure of digestion) per gram of volatile solids unaccounted for was highest in the digestion flask containing a 0.6 per cent concentration of the above-mentioned chloride salts (calcium chloride, magnesium chloride, and sodium chloride). The results are given in Table XI.

Unit	A (1.2% electrolyte)	B (0.6% electrolyte)	C (control)
Seed material added	2530 ml.	2530 ml.	2530 ml..
Raw sewage sludge added	6970 ml.	6970 ml.	6970 ml.
NaCl added	84.36 grams	42.18 grams	0
$CaCl_2$ added	17.78 grams	8.89 grams	0
$MgCl_2$ added	11.86 grams	5.93 grams	0
Total solids reduced	350 ppm.	764 ppm.	1462 ppm.
Total volatile solids reduced	321 ppm.	590 ppm.	985 ppm.
Total volume of gas produced	137 ml.	1379 ml.	1882 ml.
Total volatile solids reduced	3.05 grams	5.60 grams	9.36 grams
ml.gas/gram vol.solids reduced	44.9 ml.	246.3 ml.	201.1 ml.
Time in hours	188 hours	188 hours	188 hours
Rate gas prod./hour	0.734 ml.	7.34 ml.	10.01 ml.

Joint Committee Field Tank

It is planned to construct a 500-gallon Joint Committee tank in the field to permit comparison of the field results with the results obtained in the laboratory. A site has been found and construction of the tank

should begin shortly. The tile field will also be laid and will be available for study. It is hoped that it will be possible to modify the construction on the various tile branches to note what benefits may have occurred due to the type of construction applied.

Grease

Laboratory experiments will be set up to determine the effect of the addition of grease in varying amounts on the build-up of scum, and the rate of digestion of the grease so added.

Miscellaneous Future Work

Several tile lines are planned in relatively impervious soil. Amounts of gravel and methods of laying will be varied. The effect of these factors on the operation of tile lines will be noted.

Moisture contents of soils in sodded and unsodded areas will be determined to note possible differences in values. The effect of laying tile fields in sodded and unsodded areas will be studied.

4. Locate, construct, or otherwise secure at properly selected field locations and operate, under normal conditions, tanks of some flexibility for trials and pilot studies.

5. Locate, construct, or otherwise secure at properly selected field locations and operate subsurface systems on experimental basis, including experimental seepage test holes, trenches, tile lines, and complete subsurface installations.

Progress on both of these items is reported in detail in other parts of the study, principally under Project No. 3, wherein the operation of the battery of tanks at the Laboratory was undertaken in lieu of the operation of tanks in the field for which no suitable central location could be found and in connection with which the location of various tanks at scattered locations on individual households was considered difficult to operate and subject to individual variation in sewage and pattern. None the less the sampling and gaging studies will contribute information, as well as control on the installations, as will a Joint Committee tank to be installed in the field as a control.

A start has been made on the construction of experimental subsurface trench systems and study of seepage test holes and tile line grades is under way. In connection with installation of the Joint Committee tank in the field negotiations are under way to construct a subsurface installation for experimental operation.

6. Initiate sampling, gauging, and testing of several installations representative of current practices.

As indicated under project 1B previously sampling and gaging got under way July 29th.

7. Conduct laboratory investigations on the soil-clogging characteristics of tank effluent.

As indicated under Project No. 3 apparatus is being set up to dose experimental tubes of sand or earth with pure cultures and with sewage in an effort to identify clogging organisms and to investigate the effects of dosages of sewages settled for varying periods of time including septic sewage.

Some 35 references were corresponded with in an effort to locate a soils scientist. While negotiations are still in progress no definite commitments have been obtained thus far.

An account of some of the exploratory work done thus far on this project is presented in Project 3 under Soil Absorption Studies, Clogging Characteristics.

8. Study the economic and general feasibility of constructing systems with sufficient sludge capacities to require cleaning at only 10 or 20-year intervals.

Solicitation of cost data on septic tanks, systems and cleaning services is in progress. With these and a fair range of scum and sludge accumulation figures, available from field reports, further attention will be given to the proposition.

9. Study the effect of extreme freezing conditions on the functioning of a properly designed and constructed subsurface disposal field and determine what modifications should be incorporated in accepted design practices for cold climates.

In the northern United States the problem of freezing of all or parts of a septic tank system must be considered. From a preliminary review of health department regulations of states in cold climates, it appeared that the systems were placed fairly deep in the ground to prevent the occurrence of freezing. To ascertain if this problem was acute the literature was checked for references, and a survey conducted of plumbers in these colder regions.

A one winter study of a tank connected to the Physics Building at the Ontario Agricultural College showed that no part of the system froze. Though air temperatures dropped as low as -6°F, the lowest temperature in the tank was 34°F, and 34°F in the 2 ft. deep tile field. Flood in the 1944 Sewage Works Journal states "There has been some misconception about the necessity of placing the tile in the field below the frost line to prevent freezing in the New England area during the winter. A large number of such fields, in which the tile is placed on the average 18 in. below the ground surface, have been operating successfully in New England for many years."

During June 1947, 61 plumbers in northern areas were contacted by letter, and 20 replies have been received to date. The names of these plumbers were obtained through the cooperation of a septic tank manufacturer, who was asked to furnish names of plumbers who would have to maintain as well as install septic tank systems. It was felt that such plumbers would have intimate knowledge of systems from an operating standpoint.

The letter to these plumbers included the following questions.

1. What is the usual practice in installations with which you are familiar in your locality, as to the depth of the house sewer, the tank and tile field?
2. Do you know of any tile fields 18" to 24" below the ground surface?
3. Do these shallow systems freeze if in constant use?

4. What part of the system freezes first; the sewer, the tank, or the tile field?

5. Are any special precautions taken, such as covering the tank and field with hay or manure, or other measures?

6. Are dosing siphons generally used?

7. Do you know of any cases where a shallow system installed in the Fall freezes the first Winter and operates satisfactorily after that? What about installations made in the Spring in this connection?

8. Are the lines of the absorption field vented to the ground surface? Have you found any difference in operation, with respect to freezing circumstances between vented and unvented tile fields?

From the answers received it appears that usual practice is to place the systems about 1 to 3 feet below the ground surface. Only three plumbers mentioned depths of 6 ft. or over. Of those plumbers responding to the question concerning shallow systems and indicating knowledge of such systems only two stated that they would freeze. Of these two, one stated that his experience with septic tank installations was very limited, and the other stated that the system would freeze only if there were no snow cover. In response to the question concerning the part of the system to freeze first, the answers were quite variable covering all parts of the system with three stating that no freezing occurred, another that he knew of only one case, and another that the sewer froze if the faucets in the house leaked.

Of 16 replies received to the question concerning insulation of the system during the winter, 8 replied that special precautions were taken. In all cases the plumbers reported that dosing siphons were not generally used, but some indicated that they were used on large installations. Eight replies were received indicating knowledge of freezing of systems installed late in the Fall during the first Winter, and operating satisfactorily after that. This question was asked with the thought that a system installed after warm weather

and not seeded, would not have time to start septic action before the advent of cold weather. Thus, the heat afforded by digestion would not be available to help prevent the tank from freezing. From the answers received it appears that this happens more than occasionally, and that systems installed late in the Fall should be properly seeded to prevent freezing during the first Winter. Only two replies indicated that all tile fields were vented, and two others stated that a few tile fields were vented. One plumber stated that a vented system freezes more readily than an unvented system, while another stated that venting made no difference.

From the results of this survey and the statement made by Flood, it appears that freezing is not a serious problem in properly designed, and continuously operated systems. It is also indicated that the depths of cover commonly thought necessary are much greater than are actually necessary to prevent freezing. It is planned to carry this survey further in the very near future. Another list of plumbers including over 100 names has been obtained, and a questionaire will be sent to them to obtain additional data on freezing of septic tank systems.

The results from this second solicitation together with the information already on hand will be studied to determine if additional information is necessary. If further study is indicated, field work will be conducted in Northern areas next Winter.

10. Study the effect of tree and shrubbery roots on disposal systems and the ability of roots to absorb significant portions of sewage effluent through all seasons of the year.

A review of the literature on this topic is about one-third complete.

11. Determine the effect of residential garbage grinding on septic tanks operation and what modifications in design should be made to permit this service.

The use of home garbage grinder units in dwellings equipped with septic tanks increases the organic load placed on the system. No factual data are available concerning the effects of garbage on a septic tank system. Consequently, study of the quantity and characteristics of garbage and its probable and possible effects on the system, at least as a start, is indicated.

Quantity - The quqntity of garbage produced per person varies quite considerably from locality to locality, during different months of the year, and even from year to year in the same locality. Many writers have assumed the per capita garbage production to be 0.5 lb. daily in discussing the digestion of garbage with sewage sludge. Data from Hering and Greeley[1] on 33 selected American cities give a median garbage production of 168 lbs. per capita per year, or 0.45 lb. daily. The American Civil Engineers Handbook[2] gives data from 20 American cities which show a median garbage production of 188 lbs. per capita per year, or 0.515 lb. daily. The following data are from Refuse Collection Practice published by the American Public Works Association.[3]

Quantity of garbage collected (48 cities - 1939):

		lb./cap./year	lb./Cap./day
Normal Range	Minimum	70	0.19
	Lower 1/4 point	177	.48
	Median	235	.64
	Upper 1/4 point	333	.91
	Maximum	552	1.51

This report states that the median figure represents an average community. The normal range of garbage production is between 0.48 and 0.91 lb./cap./day. Data from a U. S. Dept. of Agriculture[4] survey show the following garbage production for the 10 largest American cities for a one-year period:

City	lb./cap./year	lb./cap./day
New York	328	0.90
Chicago	212	.58
Philadelphia	203	.56
Detroit	246	.67
Los Angeles	285	.78
Cleveland	281	.77
Baltimore	197	.54
St. Louis	196	.54
Boston	291	.80
Pittsburgh	313	.86

The following chart shows the monthly variation in garbage production for the average rates in eight cities, and has been prepared from data presented in Refuse Collection Practice. The second chart is for nine cities, and the data are from Hering and Greeley.[1] The maximum rates occur in the late Summer months when the use of fresh vegetables is at its peak. The APWA data show that the maximum monthly rate is 151.2 % of the average, and the minimum is 69.6 % of the average. Tolman[5] reporting on four years' data from Lansing, Michigan, stated that the minimum monthly rate is 82% of the average and the maximum 165% of the average.

Garbage production by geographical areas is given in the USDA report and is shown below. These data were obtained from 247 cities of over 25,000 population and represent 60% of all cities over 25,000 population and include 79% of the people in this total population group.

Garbage production for 247 cities during one year, 1939-40:

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Area	lb./cap./year	lb./cap./day
New England	242.1	0.66
Middle Atlantic	306.2	.84
East North Central	315.4	.86
West North Central	247.6	.68
South Atlantic	373.3	1.02
East South Central	383.9	1.05
West South Central	285.5	.78
Mountain	241.1	.66
Pacific	270.5	.74

The data from this report show much larger per capita figures than data from any other source. However, pounds of garbage as reported in this paper includes estimates of all garbage collected whether by public or private sources.

From the data cited above, it appears that 0.65 lb./capita/day more nearly represents present conditions than the commonly used figure of 0.5 lb.

The following two tables give data from Hering and Greeley[1] relative to the quantity of grease in garbage:

Quantity of Grease in Garbage

City	%
New York - Sample A	7.07
B	3.52
C	7.22
D	6.82
E	2.83
Milwaukee, Wis.	1.93
Cincinnati, O.	4.02
Cleveland, O.	3.85
Columbus, O.	3.96
Dayton, O.	3.83
Washington, D.C.	5.12
Los Angeles, Calif.	1.71
Chicago, Ill.	2.04

Quantity of Grease in Garbage, %

City	1914	1915	1916	1917	1918	1919
Detroit*			2.4	3.0	2.9	
Cleveland	2.95	2.81	3.06	2.83	2.36	2.55
Columbus	2.74	2.21	3.08	2.3	2.16	
Minneapolis				1.0		

* Data for 4 months of each year.

From the data presented above, it may be assumed that the average moisture content of garbage will be approximately 80%, with about 90% of the total solids being volatile. The quantity of grease in garbage may be assumed to be approximately 2 to 3% of the total weight.

Composition - The composition of green garbage varies considerably among different localities. The information available in the literature on this subject is quite limited in scope. Rudolphs[6] states that the moisture content of garbage varies from 70 to 90%, and gives the following table showing the variations in garbage solids composition as compared with sewage solids:

	Garbage	Sewage Solids
Volatile solids, %	80-90	70-80
Ash, %	10-20	20-30
Grease, %	13-33	15-35
Nitrogen, %	0.4-1.5	4-6

Tolman[5] reports the following data concerning the composition of garbage at Lansing, Michigan:

Year	lb./cap./day	% moisture	% solids	% volatile solids
1942-43	0.68	83.9	16.1	91.1
1943-44	.61	83.1	16.9	87.9
1944-45	.66	82.2	17.8	87.2
1945-46	.68	80.9	19.1	87.5

Hering and Greeley[1] give the following data concerning garbage composition:

City	Year	% moisture	% solids	% volatile
West New Brighton	1905-06	73.26	26.74	63.2
Milwaukee	1910	70.6	29.4	59.9
New York	1905	71.4	28.6	81.8
	1907	68.50	31.5	72.0
Washington	1916	73.85	26.15	86.1
Cincinnati	1909-10	76.6	23.4	84.2
Cleveland	1909-10	75.6	24.4	86.9
Columbus	1909-10	76.4	23.6	86.0
Dayton	1909-10	80.6	19.4	86.6

The composition of garbage at Indianapolis reported by Tolman(7) shows the moisture content to be 82.5 % and the petroleum ether soluble matter 2.01 %. These data are averages of 74 samples during the latter half of 1935.

Effects of Dual Disposal - The factors of dual garbage-sewage disposal which may affect the operation of a septic tank system are:

1. Possible clogging of the sewer line.
2. Increased quantity of sludge.
3. Increased quantity of scum.
4. Increased quantity of grease.
5. Increased rate of gas production and change in character of gas.
6. Increased solid load on disposal system.

The first consideration above affects only the transportation of the sewage to the tank, and may be resolved by insuring that the sewer line is of adequate diameter and laid on sufficient slope to prevent stagnation. Cohn makes the following statement concerning the effect of garbage-sewage material on house sewers: "It is the consensus of opinion that home grinders produce no stoppage in drain lines. In fact, the bulk of testimony is that former sluggish drains are no longer sluggish, due to the high speed scouring action of the home grinder unit." Tolman(7) states

that the Schenectady, N.Y., plumbing inspector reports no stoggage from home grinder units on the basis of 400 to 500 installations. In view of these considerations, it appears that stoppages due to ground garbage are infrequent.

The second to fifth factors above apply primarily to the design of the septic tank unit. The sixth factor may be considered as applying only to the effluent disposal system, however, it would be better to apply it primarily to a consideration of the tank design. This will then resolve all factors into a consideration of the effects on one unit of the system. However, it is not probable to expect that a septic tank will remove 100% of the additional solids, but the tank should be designed to approach this limit in order to modify the effect of the increased solids on the effluent disposal system.

Quantity of Sludge - The quantity of sludge accumulated as a result of the addition of garbage solids is dependent on several factors:

1. Quantity of total garbage solids added.
2. Quantity of suspended garbage solids added.
3. Quantity of suspended solids retained to undergo digestion.
4. Rate of digestion and volatile solids loss.
5. Compaction of sludge.
6. Time between sludge withdrawals.

To predict the quantity of accumulation of sludge considering these factors would involve the use of many assumptions. The quantity of garbage solids can be given with a fair degree of assurance, but the quantity of suspended solids is less certain. Tolman[5] reported that suspended garbage solids at Indianapolis were 74% of the total garbage solids, and that comparable results had been obtained at Marion, Indiana. If per capita

garbage production is assumed to be 0.65 lb. daily of 75% suspended solids and 80% moisture content, the suspended solids load per person will be approximately 0.1 lb.

No information is available concerning the removal effected by a septic tank, nor of the rate of digestion. Hence, it is impossible at the present time to estimate the quantity of sludge produced by dual disposal.

Quantity of Scum - It is logical to assume that the quantity of scum produced by combined disposal will greatly increase. Various sewage treatment plants digesting a mixture of garbage-sewage solids have shown increased quantities of scum which have, in some instances, interfered with the proper operation of digestion units. This problem has been largely overcome by frequent recirculation of the digester contents. This method of attack is impossible with present septic tanks, hence consideration must be given to the provision of sufficient additional capacity for the accommodation of scum.

Gas Production - The dual digestion of sewage and garbage solids will produce increased quantities of gas. If the garbage volatile solids are assumed to be equal to sewage volatile solids, then at least an additional equal quantity of gas might be expected. However, some investigators have reported that the quantity of gas from garbage is larger than that produced from an equal quantity of sewage solids. Bloodgood[8] stated that the quantity of gas produced per unit of volatile garbage solids is at least twice that produced from primary and

activated sludges. Malcolm's[9] experiments at Cornell showed that only a slight increase in gas production was obtained by digesting garbage solids alone, and none when they were digested in combination with sewage solids. Rudolphs[6] in summarizing conclusions from various sources, reports that the amount of the gas produced from mixtures of garbage and sewage solids is about the same as from sewage solids alone on an equal volatile solids basis.

The composition of gas from dual digestion is not much different than that produced by sewage solids alone. In general, slightly larger quantities of CO_2 and less N_2 are produced due to larger amounts of carbohydrates and less of nitrogenous material in garbage solids.

Solids Load on Disposal System - The last factor to be considered is the increase in solids which must be disposed of by the effluent disposal system. If it is assumed that the removal of garbage solids is no greater than that of sewage solids, then the disposal field must be able to take care of approximately twice the solids load. However, it is reasonable to assume that a larger proportion of garbage solids will be deposited in the tank than the proportion of sewage solids. There is, however, no factual information to support this assumption. In any event, the tile field should be designed with additional ample capacity to satisfactorily dispose of the increased loading.

Proposed Work

Plans have been made for the operation of a garbage grinder which has been purchased for the purpose at the laboratory, in connection with the operation of a second 500 gallon Joint Committee to be added to the battery of tanks in operation. A 500 Joint Committee tank now in operation as one unit of the battery mentioned will serve as a basis of comparison. It is expected to develop the location of garbage grinders now discharging to septic tanks at an impending conference with a representative of the General Electric Co., following which field examinations will be made.

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12. Test various distribution box installations as a basis for determining the most efficient design for these structures.

A review of practices and research has yet to be made before working on this problem. Such experimental work as indicated can be handily carried out above ground at the Laboratory.

13. Investigate feasibility of changing the ratio of horizontal and vertical areas of septic tanks so as to permit a shorter detention period and increased sludge storage capacity.

Comparison of operating efficiencies of the battery of tanks at the Laboratory indicate that this topic is well worth attention. Efforts will be made in future runs to sample each of the tile stacks in addition to the effluent of the series, which together with the investigation into soil clogging characteristics of fresh and septic settled sewages should pilot the way to further investigation.

14. Study the discharge of normal amounts of grease directly into a septic tank of adequate size and determine the effect of grease on septic action and on the efficiency of septic tank systems.

Laboratory experiments will be set up to determine the effect of the addition of grease in varying amounts on the build up of scum, and the rate of digestion of the grease so added. To complement these Laboratory investigations, the literature will be surveyed to obtain available information concerning the subject.

15. Determine the relation of Sodium and Calcium to the soil-clogging action of the effluent.

Although there has been no opportunity to start work on this project it

might well be deferred till the employment of a soils scientist with a saving in time and possible avoidance of repetition.

16. Investigate the relationship of (a) seepage, lateral or vertical (b) evaporation and (c) transpiration to the overall efficiency of a subsurface disposal system.

Progress has been made in review of the literature on this project. The review is approximately 50 per cent completed at the present time.

17. Study and investigate new methods of disposal, particularly substitute methods for subsurface disposal.

As this study progresses further, it is planned to initiate investigations concerning possible new methods of treatment. Some work is now being carried out in other laboratories on the treatment of whitewater wastes with supersonic waves. According to information obtained, these waves coagulate some fibers and sterilize the system. In addition to the possibility of determining the feasibility of using such a method for treating domestic sewage, it is planned to investigate the possible use of electronic coagulation. It is also hoped that some new methods for the disposal of the septic tank effluent may be developed, or that improvements on old methods may be made.

18. Develop recommended minimum standards of design for septic tank systems.

The development of standards will be taken up at the completion of the work upon which they are to be based. Efforts will be made to obtain analytical data on tank performance insofar as possible to attempt the formulation of performance standards as may or may not be feasible. In any case a set of specification standards will be prepared.